

小菜蛾生物学的研究:生活史、世代数及温度关系*

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摘要 小菜蛾 (*Plutella xylostella* L.) 广泛分布于世界各地。在杭州郊区,近年来上升为最重要的十字花科害虫。为害猖獗时可减产3—5成。

1973—1974年的研究表明,在杭州实验室条件下,小菜蛾一年可发生9—14代,世代重叠。在田间,各个季节都能见到四种虫态,没有越冬滞育现象。

成虫产卵期可以近于或长于下一代的幼期历期。这是世代重叠的一个重要因素。九月份达到世代重叠高峰,每旬七代重叠,而从整个九月份看,可有八代重叠。

在杭州室内最适气温条件下,发生一代仅需9—10天;而冬天完成一代却要110天。卵、幼虫和蛹的全年残存率分别为75.62%, 80.21%和93.60%。

幼期历期与日平均温度间的曲线回归方程为 $\hat{Y}_0 = 1997X^{-2.0625}$, $\hat{Y}_1 = 4345X^{-2.0218}$, $\hat{Y}_2 = 2427X^{-2.0025}$ 。

据报道世界各地有小菜蛾记录的国家 and 地区不少于84个(Hardy, 1938)。几乎凡有十字花科植物生长的地方,都有小菜蛾的为害。

据我们田间调查,目前杭州郊区为害十字花科蔬菜的主要鳞翅目害虫有菜粉蝶(*Pieris rapae* L.)、小地老虎(*Agrotis ipsilon* Rot.)、斜纹夜蛾(*Prodenia litura* Fab.)、银纹夜蛾(*Phytometra gamma* L.)、棉铃虫(*Heliothis armigera* Hüb.)和小菜蛾(*Plutella xylostella* L.)等六种。偶然也有少数粉斑夜蛾(*Trichoplusia ni* Hüb.)为害。其中仅小菜蛾是终年为害,其余几种都是间发性的。

在小菜蛾大发生年份或季节,萝卜、甘蓝、大白菜、花菜、茼蒿等受到严重为害。此外还为害十字花科油料作物,有时给温室油菜育种工作者带来许多麻烦。在防治上虽经常连续喷用敌百虫、敌敌畏二种农药,但还不能控制为害。为此急需研究它的发生规律,为综合防治提供依据。此文仅报道小菜蛾的生活史、世代重叠现象和幼期历期与日平均温度之间的关系等研究结果。

材 料 和 方 法

研究工作从1973年10月到1974年10月在杭州实验室内进行。田间采回小菜蛾蛹,分别放入500毫升的玻璃瓶内,成虫羽化后当天雌雄配对,编好号,产下的卵作为饲养中的第一代卵。

瓶内悬挂新鲜菜叶一张,供成虫产卵。在瓶底铺一层与瓶底相似大小的滤纸,并放一个吸有25%葡萄糖溶液的棉花球,供成虫取食。瓶口用纱布扎紧。逐日记录产卵量、寿命

本文于1978年2月收到。

* 本研究得到浙江农业大学植保系唐觉教授的鼓励和指点;宽桥公社井岗山大队夏文英同志协助养虫,谨此致谢。

及其他变化。所产之卵按下述生活史研究设计进行饲养试验,留一定数量用以传代。

卵放在 13 厘米的培养皿内,借湿润滤纸保湿。滤纸上放一块新鲜菜叶,置卵于其上。幼虫孵化后用同种培养皿饲养。将初孵幼虫放在 2×3 厘米的新鲜菜叶上,每叶二条。每皿放互相分开的菜叶 3—4 片,并按顺序编号。幼虫潜叶后,每小片叶上仅留一头,即每皿养 3—4 头。老熟幼虫分别移入 1.5×15 厘米的试管中,并放小块菜叶,管口用纱布扎好,管底朝上,让其化蛹、羽化。

为了防止连续饲养中的退化(经过连续饲养十代左右后成虫体小,产卵量少),陆续从田间采回一批蛹,以保证生活史饲养中的羽化成虫与当天羽化的外来成虫配对传代。

卵、幼虫、蛹在周年饲养中,每天上、下午各观察一次,每次观察结果分别记录。

作饲料用的一切菜叶(根据生产上当时的蔬菜类型而定,一般用甘蓝、花菜,有时也用青菜、大白菜)都经仔细检查,防止带有任何虫态的小菜蛾。

同时进行了世代重叠与生活史的研究。每号虫的第一代卵分别取最早、中期和最迟三组,并以 A、B、C 来代表之。研究中,它们的后代凡 A 组的专取第一天所产之卵; B 组的专门取第五天所产之卵(一般情况下成虫卵期在十天以上); C 组的专门取十天之后直至最后一天所产之卵。在 A、B、C 组中,各虫态因发育速度的不同,选取传代用的虫态仍按上述原则决定取舍。这样,通过一年复杂的生活史饲养,每对小菜蛾就产生了不同世代数和它们的世代重叠情况。我们试图用它来全面地观察生活史循环。在生活史的研究中,一般 C 组的卵自第十天开始取,直至最后,但 C 组的幼虫始终是取最迟孵化的一批。B、C 组的具体取卵日期还按温度变化而灵活掌握。

在整个生活史研究期间,共观察了卵 19,657 个,幼虫 3,330 头,蛹 2,533 头,成虫 1,592 对。实验室温湿度由周自记器自动记录,同时记录幼虫食料的变动情况。

结 果

1. 生活史

室内饲养和田间调查证明,在杭州,小菜蛾没有越冬滞育现象。任何季节都能找到四种虫态。但冬末春初,由于低温,田间虫口大量死亡,不死的发育亦十分迟缓。11 月后发生一代需要 110 天(11 月到 2 月平均温度为 $8-9^{\circ}\text{C}$); 而 7 月底 8 月初,平均温度 $28-30^{\circ}\text{C}$ 时,发生一代仅需 9—10 天。由于世代严重重叠,这里只能选择有代表性(指饲养得较为完整, A、C 世代相差最大)的虫(饲养编号 64)作出生活史表。详见表 1。由表 1 可见,在杭州,小菜蛾一年可发生 9—14 代。这种差异主要是由成虫的产卵习性所引起的。根据各代成虫的产卵规律,大致有 20—30% 的虫一年可发生 14 代,极少数(约占 1—2%) 虫一年发生 9 代,而 70% 左右的小菜蛾一年发生代数介于 9 到 14 代之间。

2. 世代重叠

我们看到小菜蛾的成虫羽化当天即始产卵,产卵期可持续到死亡前一天。表 1 大致表达了杭州郊区小菜蛾的世代重叠情况。以月份为时间单位来看(这样看便于解释自然界的消长情况),3 月二代重叠,4 月三代重叠,5 月四代重叠,6、7 月六代重叠,8 月七代重叠,9 月八代重叠,10 月七代重叠等等。以旬的时间单位来看,9、10 月各旬都为七代重叠。同一对祖先,经过各世代繁殖之后,早迟之间一年可以有五代的相差。对于没有越冬

表1 小葉鎮生活史及世代重疊表

月 旬	11			12			1			2			3			4			5			6			7			8			9			10		
	上	中	下	上	中	下	上	中	下	上	中	下	上	中	下	上	中	下	上	中	下	上	中	下	上	中	下	上	中	下	上	中	下			
代	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
組																																				
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现象并且世代重叠复杂的昆虫来说,生活史研究的起点和虫态的确定是一件十分困难的事。我们是以秋末冬初的蛹为起点进行研究的,因此上述的重叠形式也是在这个特定条件下得到的。倘若起点和虫态与此不同,重叠的形式也一定会有变化。但是,在杭州的情况下,至少有一部份小菜蛾是按表 1 的情况重叠的。并且由于 7、8、9 三个月气温高,小菜蛾的发育速度快,因此这三个月的世代重叠总是最为复杂。

小菜蛾世代重叠的原因之一是它对环境的适应性强(Hardy, 1938)。我们看到小菜蛾的产卵期可以近于,以至长于它的幼期。从表 2 可见,成虫产卵期最长可达 98 天,产卵历期可以超过下代幼期 67 天。这样,经过数月繁殖之后,为暴雨较少的秋季、在生长期较长的十字花科作物,如大白菜、萝卜和甘蓝等作物上造成严重为害积累了可观的数量基础。这是杭州郊区秋季小菜蛾严重猖獗的重要原因。

3. 幼期各阶段与日平均温度间的关系

在生活史研究中我们选择有代表性的卵几百粒、幼虫 171 头和蛹 141 头分析了发育历期与日平均温度之间的关系(温度按 24 小时 12 次记录得到的平均数),结果见表 3、4 和 5。

表 2 成虫产卵期与幼期历期比较的实例

饲养虫号	羽化日/月	产卵历期 (天数)	本代幼期历期 (天数)	下代幼期历期 (天数)	产卵历期超过下代幼 期历期(天数)
11B ₁	20/XII	98.0	54.5	31.0	67.0
12A ₄	1/VI	19.0	16.0	18.0	1.0
18A ₁	3/I	85.0	71.0	58.0	26.0
21A ₁	21/XII	74.0	55.0	30.5	43.5
22A ₁	13/XII	66.5	49.5	27.0	39.5
24A ₁	18/XII	61.5	54.5	30.5	30.0
26A ₆	7/XII	11.0	17.0	12.0	-1.0
36A ₁	9/I	47.0	78.0	22.0	25.0
36C ₃	25/V	26.0	17.5	17.0	9.0
69A ₂	23/IV	28.5	41.5	24.0	4.5
69A ₄	5/VI	22.0	16.5	20.0	2.0

表 3 可见,在杭州实验室条件下,小菜蛾卵的发育历期最短为 2 天,最长可达 51 天。卵发育历期与日平均温度间的指数曲线方程为:

$$\hat{Y}' = \frac{1997}{X'^{2.0625}} \quad (\text{图 1})$$

气温变化还影响了小菜蛾的孵化率;由于冬末春初羽化的成虫很多是畸形的,加之 1—3 月份气温较低,影响了成虫交尾。未受精或完成了胚胎发育而丧失孵化能力的卵较多,因此孵化率特别低,仅为 9.7—11.8% 左右。4、5 月间,气温回升,孵化率提高到 75.7—95.0%。7、8 月,月平均温在 27—28℃ 之间,有时日平均温可达 30℃ 以上,卵孵化率又下降到 50.8—75.0%。其他各月孵化率都在 90% 以上。总的感觉是成虫在 10℃ 以下所产之卵并且继续将这些卵置于同样条件下是不利于孵化的。30℃ 左右的高温有使孵化率稍微降低的趋势。另外,一般说来,成虫早期卵孵化率高,中期次之,后期最低。它们分别为 77.53%、74.99% 和 68.75%。通过全年 19,675 粒卵的观察,平均孵化率为 75.62%。

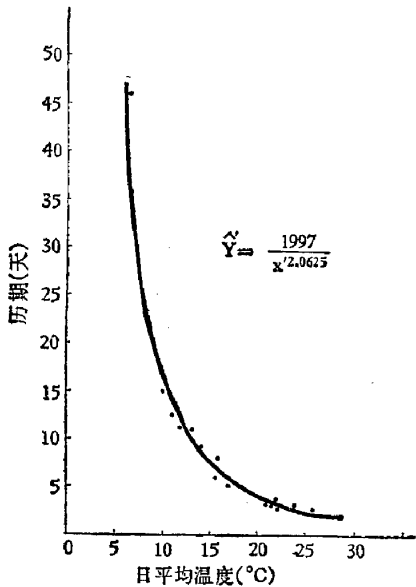


图1 卵历期与日平均温度的关系

表3 小菜蛾卵发育与日平均温度的关系

X' (发育期的日平均温度)(°C)	Y' (发育历期)(天数)	Ŷ' (理论发育历期)(天数)
29.1	2.0	1.92
25.8	2.5	2.45
24.3	3.0	2.77
22.3	3.5	3.31
20.1	4.0	4.10
17.4	5.0	5.52
15.8	6.0	6.73
14.8	8.0	7.70
13.8	9.0	8.90
13.1	10.5	9.91
11.9	11.0	12.08
11.0	12.5	14.20
10.1	15.0	16.94
9.4	24.0	19.66
6.3	46.0	44.86
6.1	51.0	47.94

表4 小菜蛾幼虫发育历期与日平均温度的关系

X' (发育期的日平均温度)(°C)	Y' (发育历期)(天数)	Ŷ' (理论发育历期)(天数)
30.5	3.5	4.28
29.5	4.5	4.58
28.4	5.0	4.94
27.2	5.5	5.39
26.7	6.0	5.60
25.6	6.5	6.15
24.1	7.0	6.89
23.6	7.5	7.19
22.4	8.0	7.99
22.2	8.5	8.14
22.1	9.0	8.21
21.8	10.0	8.44
21.1	10.5	9.02
18.8	11.5	11.39
17.9	12.0	12.59
16.8	12.5	14.32
16.1	13.0	15.61
14.5	14.5	19.29
13.4	21.5	22.63
13.3	24.0	22.98
11.8	30.5	29.26
11.0	35.0	33.76
10.1	37.0	40.16
9.1	41.0	49.58
8.1	85.5	62.75
7.0	91.0	84.34

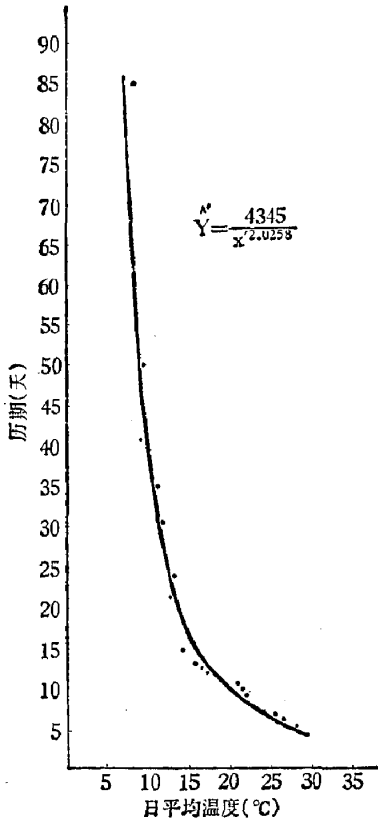


图2 幼虫历期与日平均温度的关系

全年幼虫的发育历期在 3.5 天到 91.0 天之间。幼虫发育历期与日平均温度间的指数曲线方程为 $\hat{Y}_l = 4345/X^{2.0258}$ (表 4, 图 2)。通过全年 3,330 头幼虫的观察, 得到幼虫平均存活率为 80.21%, 最高 94.4%, 最低为 40.8% (1—3 月份低温季节)。同时, 后期卵孵化的幼虫存活率也较低。

表 5 小菜蛾蛹发育历期与日平均温度的关系

X' (发育期的日平均温度) (°C)	Y' (发育历期) (天)	\hat{Y}' (理论发育历期) (天)
29.6	2.5	2.75
28.9	3.0	2.88
25.3	3.5	3.76
24.8	4.0	3.91
24.2	4.5	4.11
23.0	5.0	4.55
21.3	5.5	5.31
19.9	6.0	6.08
18.3	7.0	7.19
16.3	7.5	7.07
15.9	8.0	9.53
15.7	11.0	9.78
14.1	13.5	12.13
11.3	18.5	18.90
9.4	29.0	27.32
8.3	40.0	35.04
5.7	66.5	74.38

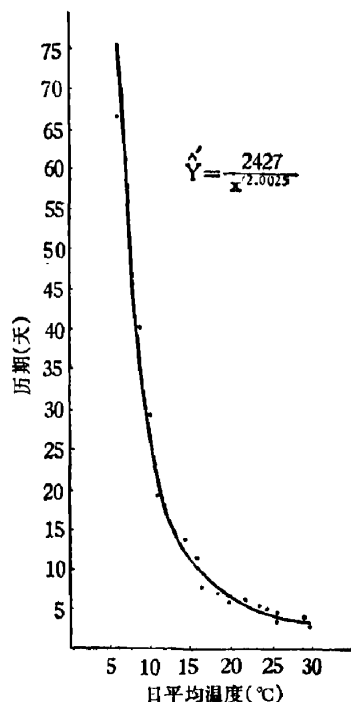


图 3 蛹历期与日平均温度的关系

全年蛹的发育历期在 2.5—66.5 天之间, 发育历期与日平均温度间的指数曲线方程为: $\hat{Y}_p = 2427/X^{2.0025}$ (表 5, 图 3)。全年蛹的存活率比幼虫高, 比卵更高。在 2,533 头蛹中, 羽化率为 93.60%。同样, 冬季和早春蛹的存活率较低。在那时羽化的成虫, 经常展翅不良、生活力差、繁殖力低。用羽化前 2—3 天的蛹在 5—6°C 冰箱内贮藏二个月后放在 25°C 左右的室内, 羽化率仅为 3%, 展翅不平、活动力极差。在杭州自然情况下, 冬天幼虫的化蛹、羽化率为 77.1% 和 74.6%, 冬天蛹的羽化率为 43.4%, 比室内略低。

小 结 和 讨 论

据各国文献报道, 小菜蛾在世界各地的发生代数 1—19 代不等。在英国威尔士北部年生 1—3 代 (Theobald, 1926; Hardy, 1938)。即使在发生世代这样少的地方也有许多大爆发的记载 (French, 1960)。在苏联欧洲中部年生 2—5 代 (Пасыхов, 1964), 加拿大渥太华 4—6 代 (Harcourt, 1957, 1966), 美国科罗拉多 7 代 (Marsh, 1917), 印度马德拉斯 12 代 (Abraham, 1968)。梅谷献二 (1973) 等通过发育起点温度和有效积温的研究认为在日本札幌、平塚、鹿儿岛和印尼万隆分别每年可能发生 5、10、12 和 19 代。

在我国, 曾报道广西每年发生 17 代 (黄修明, 1942), 台湾 18—19 代 (Wu, 1968; Chow

等, 1974)。

上述研究几乎都提到了小菜蛾世代重叠繁复的问题。但是也都没有报道过具体的重叠情况。我们从研究之初就将原始亲本所产之卵分为最早、中间和最迟三个类型, 以后在周年的生活史饲养中, 最早类型、中间类型和最迟类型又分别用最早、中间和最后三类来继代。这样, 在杭州地区, 小菜蛾周年发生的最少最多世代数为 9 和 14 代。经一年繁殖之后, 同一头虫子产生的后代数最多会有五代的差异。从世代重叠的角度来看, 9 月份到了最高峰, 八代同时发生。因此 9 月之后小菜蛾为害剧烈上升。世代重叠的繁复性使残效期短的农药不能奏效。这个研究可以部分解释虽然经常喷雾敌敌畏、敌百虫, 但 9、10 月间的种群仍然较大的现象。因此, 我们认为控制小菜蛾为害的其中一个方法是选择残效期稍长的农药。据东海林修等(1975)报道, 在常用敌敌畏的地方, 小菜蛾明显地产生了抗药性。我们曾用 1,000 倍的敌敌畏和 800 倍敌百虫喷雾, 对三龄幼虫的杀伤率分别为 75.7%、12.2%。在我国, 除了小菜蛾可能对敌敌畏、敌百虫产生抗性的问题之外, 我们还认为常用农药残效期短与小菜蛾的复杂世代重叠不相适应。

Hardy (1938) 在定温定湿下进行了温度与幼期历期之间关系的研究。Miner (1947) 用日平均温度的办法观察了温度对各虫态发育的影响。Hassanein (1958) 也作了类似的观察。但是这些观察的温度范围是很有限的。我们系统地观察了周年变温条件下各虫态的发育历期, 并从中选有代表性的历期, 求出了指数曲线。这些历期与曲线可为小菜蛾的研究、预测提供参考。

Hardy (1938) 认为小菜蛾的发育起点温度在 10°C 左右。梅谷献二 (Umeya, 1973) 认为, 小菜蛾的发育起点温度随地理位置而异。如札幌为 7.4°C , 平塚为 9.5°C 等等。因此他认为可能存在着不同的生态类型。虽然我们已获得了几组数据, 但在杭州气候条件下, 小菜蛾的发育起点温度和有效积温问题有待进一步搞清。

Hardy (1938) 认为小菜蛾总是生活于蒸腾作用十分旺盛的叶表面, 那里的微气候湿度始终是很高的。在杭州生产情况下, 我们未曾看到由于大气湿度的增加而对小菜蛾有所不利。只有在室内饲养中, 如饲养器湿度过高, 幼虫就极易得病。开始体节变粗、节间内陷, 体色逐渐由绿色变为黄绿相间, 最后成黄白色。体壁极易碰破, 流出体液。小菜蛾幼虫的罹病过程及症状, 十分类似 Asayama (1970) 报道的颗粒体病毒病。虽然在自然条件下, 小菜蛾这种颗粒体病毒病见得不多, 但是它是小菜蛾大量人工饲养的大敌。近年来, Asayama 等 (1975) 对这种病毒在小菜蛾体内的繁殖、成熟过程等等作了详尽的研究。改善饲养器的透气性, 饲养工具消毒或阳光暴晒, 可以避免此病的蔓延。在生产上应用这种病毒的前景是值得研究的。

参 考 文 献

- 黄修明、李寿昆、陈绍武 1942 小菜蛾 (*Plutella maculipennis*) 生活史之研究。广西第二区农场三十年度工作报告书 143—53 页。
- Abraham, E. V., and M. D. Padamanabam 1968 Bionomics and control of the diamondback moth, *Plutella maculipennis* Curtis. *Indian J. Agri. Sci.* 38(3): 513—19 (R. A. E; A. 1971 59 (8): 311).
- Asayama, T. 1970 A granulosis of the diamondback moth, *Plutella xylostella*. *J. inver. Path.* 15(2): 284—6.

- Asayama, T. and Ikuo Inagaki 1975 Cell alternations caused by the infection with the granulosus virus in the diamondback moth, *Plutella xylostella*, and the site of appearance of nucleocapsid. *Jap. J. Appl. Ent. Zool.* (19): 79—84.
- , ——— 1975 Multiplication of a granulosus virus of the *Plutella xylostella* in Malpighian tubule. *Ibid.* (19): 115—6.
- Asayama, T. 1975 Maturation process of the granulosus virus of the diamondback moth, *Plutella xylostella*. *Ibid.* (19): 149—56.
- 1975 Proliferation of tubular structure in fat-body cell of the diamondback moth infected with a granulosus virus. *Ibid.* (19): 216—8.
- Chow, Y. S., S. C. Chiu, and C. C. Chien. 1974 Demonstration of a sex pheromone of the diamondback moth (Lepidoptera: Plutellidae). *Ann. Entomol. Soc. Amer.* 67(3): 510—2.
- Commonwealth Institute of Entomology 1953 Distribution maps of pest.
- French, R. A., and J. H. White 1960 The diamondback moth outbreak of 1958. *Plant Path.* (9) 3: 77—87.
- Harcourt, D. G. 1957 Biology of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae) in eastern Ontario II. Life-history, behaviour and host relationship. *Can. Ent.* 89 (12): 554—64.
- Harcourt, D. G. 1966 Photoperiodism and fecundity in *Plutella maculipennis* (Curt.) *Nature* 210 (5032): 217—8.
- Hardy, J. E. 1938 *Plutella maculipennis* Curt., its natural and biological control in England. *Bull. Ent. Res.*, 29: 342—72.
- Hassanein, M. H. 1958 Biological studies on the diamondback moth, *Plutella maculipennis* Curtis (Lepidoptera: Plutellidae). *Bull. Sci. Ent. D'Egypte* 42: 325—37.
- Marsh, O. H. 1917 The life-history of *Plutella maculipennis*, the diamondback moth. *J. Agri. Res.* 10(1): 1—9.
- Minor, F. D. 1947 Life history of diamondback moth. *J. Econ. Ent.* 40: 581—3.
- Theobald, F. V. 1926 The diamondback moth (*Plutella maculipennis*). *Jl. Kent. Farmers Union* 20 (3) (R. A. E., A. 14: 594).
- Umeya, Kenji, and Hideo Yamada 1973 Threshold temperature and thermal constants for development of the diamondback moth *Plutella xylostella* L. with reference to their local differences. *Jap. App. Ent. Zool.* 17(1): 19—24 (Abstracts of Ento. 5(2): 2674.)
- Wu, K. C. 1968 Bionomic study of *Plutella maculipennis* Curtis *J. Taiwan Agr. Res.* 17(2): 51—63 (R. A. E., A. 1972 60: 648).
- Пастухов, М. К. 1964 Капустная моль. Защита растений 5: 21—2.
- 东海林修、野村健 1975 コナガ 3 系統に対する DDVP および BT 剤の効果比較。日本 '応動昆' 19 (4): 298—9.

STUDIES ON THE BIOLOGY OF THE DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* L.: LIFE HISTORY, ANNUAL GENERATIONS AND TEMPERATURE RELATIONS

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The diamondback moth (*Plutella xylostella* L.) is a cosmopolitan species infesting cruciferous crops. Since the sixties, it has become an important pest on the cruciferous crops in our country, especially in the Yangtze River Valley, as well as southern and south western China, in spite of spraying with Dipterex and Dichlorophos. In order to find effective measures against this pest, we studied its biology from 1973 to 1976. This paper deals with its life history, annual generations and temperature relations.

According to the results from laboratory rearing it has 9 to 14 generations a year in Hangchow, and approximately 20—30% of the moths produce 14 generations, a few (about 1—2%) 9 generations, and the rest between 9 and 14 generations. The maximal overlap of generations derived from a single pair reared from October occurred in the next September. Under the most favourable thermal condition it took only 9—10 days to complete a generation, whereas in the winter, it took 110 days. All the developmental stages can be found throughout the year in the field in Hangchow.

The average survival rates of eggs, larvae and pupae throughout the year were found to be 75.6%, 80.2% and 93.6% respectively. Regression equations of development time to temperature for egg, larval and pupal stages are $\hat{Y}' = 1997X'^{-2.0625}$ $Y' = 4345X'^{-2.0258}$ and $\hat{Y}' = 2427X'^{-2.0025}$ respectively.